Development of Compact Proton Synchrotron Dedicated for Cancer Therapy

Akira Noda, Yoshihisa Iwashita, Akio Morita, Toshiyuki Shirai, Makoto Inoue, Kazuo Hiramoto*, Jun-ichi Hirota, Masahiro Tadokoro** and Masatsugu Nishi***

A compact proton synchrotron has been developed to be dedicated for cancer therapy. A combined function lattice and an untuned RF cavity have been adopted to realize compactness of needed cost and operation manpower. With the present design, the control of the synchrotron is also expected to become very easy for daily operation.

Keywords : Proton Cancer Therapy/ Combined Function Synchrotron/ Untuned RF Cavity / Solid State Amplifier/ Multifeed Coupling

Recently radiation cancer therapy has been paid attention from the point of view of *quality of life of the patient*, because it is superior to preserve the shape and function of the human body in addition to its merit of fairly mild load to the patient. Further charged particle therapy has such a merit as can concentrate the dose to the tumor due to the presence of Bragg-peak.

In our country, University of Tsukuba has been treating patients by proton therapy and realized a remarkable results especially in liver cancer. National Institute of Radiological Sciences has started treatment with carbon beam since 1994. In addition, East Hospital of National Cancer Center is now constructing a proton therapy facility and Hyogo prefecture is constructing cancer therapy facility with use of both proton and carbon beams. The number of patients to be treated by these facilities, however, is rather limited. Every facility can only treat 1000 patients per year at maximum and usually such number is much smaller. This limits the wide use of the benefits of charged particle therapy, because more than 30,000 patients per year need such therapy even if we only

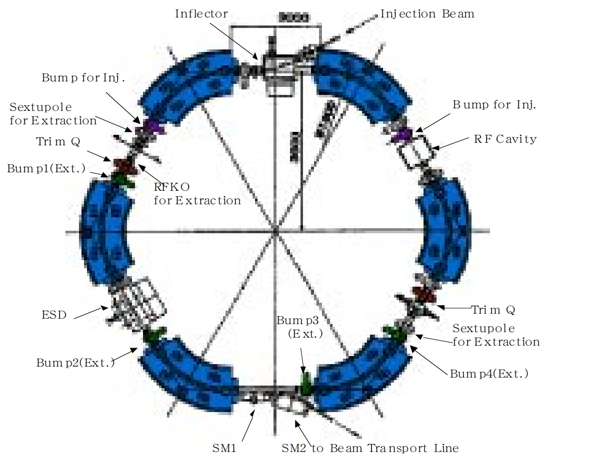


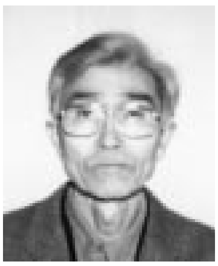
Figure 1. Lattice of the combined function proton synchrotron dedicated for cancer therapy.

NUCLEAR SCIENCE RESEARCH FACILITY — Particle and Photon Beams —

Scope of research

Particle and photon beams generated with accelerators and their instrumentations both for fundamental research and practical applications are studied. The following subjects are being studied: Beam dynamics related to space charge force in accelerators: Beam handling during the injection and extraction processes of the accelerator ring:radiation mechanism of photon by electrons in the magnetic field:Interactions in the few-nucleon systems: R&D to realize a compact proton synchrotron dedicated for cancer therapy: Control of the shape of beam distribution with use of nonlinear magnetic field: and Irradiation of materials with particle and photon beams.

Prof
NODA, Akira
(D Sc)



Assoc Prof
KAKIGI, Shigeru
(D Sc)

Instr
SHIRAI, Toshiyuki

Techn
TONGUU, Hiromu

Lecturer(part-time):
YAMADA, Satoru(Head; H.E. Acc. Div., National Institute of Radiological Sciences)
Students:
IKEGAMI, Masanori (DC)
KANDO, Masaki(DC)
SUGIMURA, Takashi(DC)
KIHARA, Takahiro (DC)
FUJIEDA, Miho (DC)
URAKABE, Eriko (MC)
MORITA, Akio (MC)
NISHI, Masatsugu(RF, D Eng)

* Power &Industrial Systems R&D Division, Hitachi Ltd., **Hitachi Works, Hitachi Ltd.
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Figure 2. Fabricated untuned cavity.

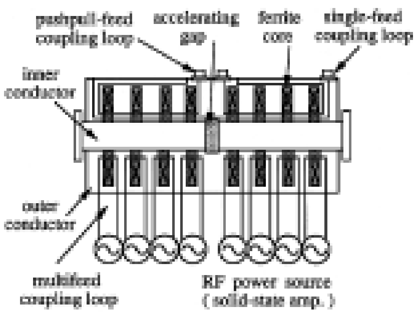

Figure 3. Schematic diagram of the fabricated untuned cavity. The cavity consists of two quater-wavelength coaxial resonators with a single accelerating gap.

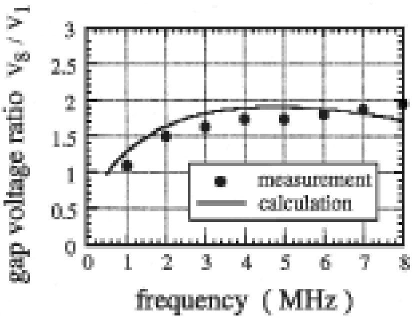

Fig.4. Frequency dependence of the gap voltage relation between multifeed coupling (V_8) and single-feed coupling(V_1).

consider the area west to Kinki district. From this point, it is required to establish a good reference design of a commercially available compact proton synchrotron which has a size acceptable for a hospital having the role as the center of each prefecture. We are proposing a combined-function proton synchrotron illustrated in Fig.1[1].

The required acceleration voltage per turn in a synchrotron is proportional to the product of time derivative of magnetic field strength, the circumference and the radius of curvature. For the presented compact proton synchrotron, only a few hundreds volts are needed as the accelerating voltage. Such a low voltage can be generated with an untuned cavity as shown in Fig.2 with a solid state amplifier, whose output impeadance is 50Ω[2]. The untuned cavity does not require complicated bias-winding for the resonant frequency tuning. In order to reduce the power reflection at the power feeder of the untuned cavity and increase the efficiency of power utilization, a new power feeding method called multifeed coupling has been invented, which is illustrated in Fig. 3[3]. By this feeding method, the power utilization efficiency is increased and thus the realized voltage at the accelerating gap has been increased as shown in Fig. 4 compared with the conventional method.

The other merit of combined function lattice is that the magnet current tracking control between power supplies for dipole and quadrupole magnets is not needed and the operation becomes very easy once a good design has been established. Because a combined function lattice has less adjustability, the magnet should be designed carefully before fabrication. This is the main reason that this type has not yet widely applied for medically dedicated machine. In order to demonstrate a good design, we are constructing a model magnet for the combined function synchrotron. Based on the magnetic field calculation with use of the three-dimensional code TOSCA, a real size magnet for the combined function lattice shown in Fig. 1

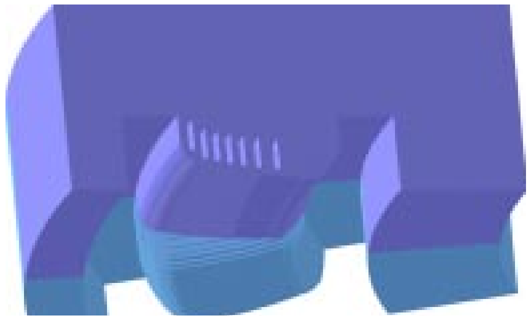

Figure 5. Configuration of the combined-function magnet. Its three dimensional magnetic field distribution is calculated with the computer code TOSCA.

is fabricated. In the iron pole, several slots are located as illustrated in Fig. 5 so as to realize good field property in the wide excitation range by equalizing the magnetic flux density in the iron pole[4]. The betatron tunes are evaluated for various excitation levels utilizing the calculated field distribution by TOSCA as shown in Fig.6. It is expected that lower order resonances up to sixth order can be well kept away from the operating point.

References

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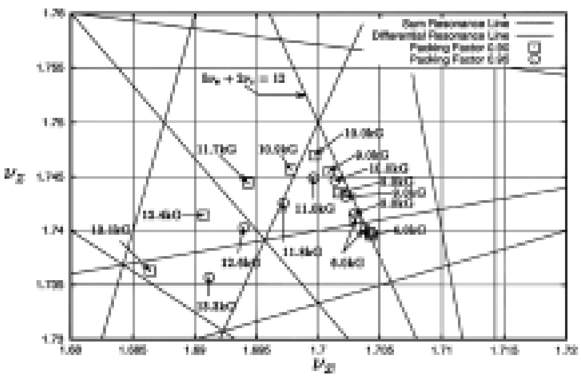

Figure 6. Operating points for various excitation levels estimated from three dimensional field calculation.